

Length measurement method by a camera with a photosensitive screen plate.

The present invention relates to a method to measure the length of an object, method according to which the object is lit in order to form the image of the shadow of said object on a detector or a camera with photosensitive screen plate, said negative image is scanned in order to obtain video signals for one scanning line and said signals are processed in order to locate the edges of said image and the distance between said edges is deduced.

A method of that type is known from EP-A-0 094 522. Following that procedure, intended for the detection of the edges of a strip, an image which can be a negative image is scanned by means of one or even two detectors or cameras with multiple photosensitive elements and the individual video signals of the elements of a scanning line are processed. First of all, the individual signal, where the variation rate of the signals is at its maximum, is defined. Followed by the definition of two other individual signals, one at each side of said signal, where the variation rate of the signals is a defined fraction from the maximum, and the average of these latter signals is formed. A signal indicating the position of the edge of the band is generated from this average. The processing of the signals of one scanning line is thus similar to the calculation of a differential coefficient.

This method is, however, only applicable when the image of the circumference of the item is sufficiently distinct, to give rise to a regular transition within the video signal. In order to attain this the profile of the observed item must be included in the focussing plane of the camera.

When, by using this method, the edges of the image of an object constituted of two cylindrical parts of different diameters, separated by a plane perpendicular to the axis of the item, are to be located, the diameters of the item are measurable with precision, because the generating lines marking the boundaries of the profile of the cylindrical parts are contained in the focussing plane. On the other hand, the image of the face of the item observed in profile by the camera appears out of focus. The out of focus field spreads over several scanning lines on both sides of the real position of the sides. Moreover, the video signal is disturbed in this field by reflexions of parasite lights on the face, in such way that the position of the faces within the image cannot be defined accurately by the aforementioned method. The processing of signals according to EP-A-0 094 522 is not applicable to an irregular signal.

The invention is aimed at remedying these inconveniences and to be able to provide for a method for the measurement of lengths by a camera with a photosensitive screen plate allowing for precision localization, in the negative image, of the faces parallel to the focussing axis of the camera, thus allowing the measurement of, for instance, an item constituted of two cylindrical parts of different diameters separated by a plane which is perpendicular to the axis of the item and observed in profile.

In order to achieve this, the image is scanned along several scanning lines, at least in the neighbourhood of the edges, the video signals are integrated over all or part of each of these scanning lines, the evolution of the integral's value over several successive scanning lines in the neighbourhood of the edges to be localized is followed and points are defined in the curve representing that evolution of the integral corresponding to the edges on the negative image.

The integration of a video signal in a measuring method is known as such in US-A-4 650 335, but that method is not of the kind in which the image is a negative image formed by the shadow of an object. It is based on the use of a laser beam which scans the surface to be inspected and reflected by the latter. This inspection method compares the intensity of a laser beam reflected from the object to that of a laser beam reflected by a reference object. The signals corresponding to the detected intensities by the individual detection elements of a same scanning line are integrated and the localization of the edges of the reflected image is defined from this integral.

This method, which furthermore is destined for the measurement of microscopic differences in thicknesses, allows to localize, by comparison, differences in level perpendicular to the scanning line but is not applicable to the observation of faces of objects presented in profile with respect to the camera. Thus, this method does not resolve the aforementioned problem.

In the method according to the invention the position of the edges in the image of the object can be localized in many ways.

In a particular embodiment of the invention, the position of the edges in the image of the object is localized by differentiating twice the integral curve and by localizing the locations corresponding with the maximums of the secondary differential coefficient within the fields where the absolute value of the primary differential coefficient is higher than the threshold which has been experimentally determined.

In another particular embodiment of the invention, the position of the edges in the image of the object is localized by localizing the locations corresponding with

the maximums of the correlation function of the second derivative of the integral curve with an empirically defined filter and including the deformations resulting from faults in focussing.

In order to better clarify present invention, examples of the method according to the invention are described hereafter as illustration and without any restrictive character, with reference to the attached drawings, in which :

figure 1 shows the measurement principle according to the invention ;

figure 2 shows the video signals corresponding with the scanning lines B in the neighbourhood of the face ;

figure 3 shows an integral curve ;

figure 4 shows a localization criterion of the face ;

figures 5 to 7 showing still other criteria ;

figure 8 shows a particular measurement problem in which the video signal is partially integrated.

As shown in figure 1, an object to be measured 1, of axial rotation, is placed in front of a camera 2 consisting of a lens 3 and a photosensitive detection unit 4. The axis of the object to be measured 1 is placed in the focussing plane 5 of the camera 2 in such way that the image of the object to be measured 1 is correctly focussed on the photosensitive surface of the detection unit 4.

The item to be measured 1 is lit by a collimated light source 6, parallel to the optical axis 7 of the camera 2 and located behind the item 1 with respect to it, in order to form, not the image of the object 1 on the detection unit 4, but the image 3 of its shadow.

The image 3 observed by the photosensitive screen plate 4, by means of electronic circuits which are not shown in

figure 1, is scanned line by line. The video signals 7 thus obtained, more particularly the video signals V corresponding with the scanning lines BI near the face 9 are perturbed, for reasons explained above, as shown in figure 2, and do not provide any data directly useful to delimit with precision the position of the face 9.

The method according to the invention, which allows to resolve this problem consist substantially in integrating the video signal V of each of the scanning lines BI, to follow the evolution of the integral I during the successive scans BI, in the neighbourhood of the face 9, and to localize precisely, in the integral curve I, those points corresponding with the sides in the image 8 of the object to be measured 1.

The value of the integral I represents the total quantity of light received by the camera 2 along a scanning line BI and varies at of the face 9, which corresponds with to an abrupt change of the observed profile. In practice, the variation of the integral I at the face 9 is not abrupt, but owing to the lack of definition around the face 9, it follows a regular curve as shown in figure 3.

The precise localization of the face 9 along this curve can be achieved following a variety of criteria, the choice of which depends on the type of lighting 6 used and the characteristics of the item 1.

One of them consists in defining the point of inflexion of the curve.

Another one consists in the detection of point F where the curve I reaches a fixed percentage P of its total variation as shown in figure 4. This percentage P can be defined experimentally during the calibrating of the

instrument.

Yet another criterion consists in differentiating the signal integral I signal twice and to mark particular points which are characteristic of the faces 9 on the curve thus obtained.

A first differentiation $D1$ is obtained by calculation of the successive differences of the values of integral I obtained after each scan BI of the camera 2. The second derivative $D2$ is obtained through the successive differences of the values obtained through the calculation of the first derivative $D1$.

The position of the faces 9 is defined, as shown in figure 5, by locating the positions of the positive maximums $P1$ and $P2$ in the curve of the second derivatives, i.e. the points corresponding with a maximum bend in a defined direction in the integral curve I .

In order to eliminate parasitic detections which might ensue from the presence of noise in the second derivative signal $D2$, the fields in which detection is achieved are limited to the locations where the absolute value of the first derivative $D1$ is higher than an experimentally defined threshold $S1$.

The method of localization of the faces 9 based on the detection of the position of the maximums $P1$ and $P2$ of the second derivative curve $D2$ can still be refined by replacing the search for the positions of the maximums $P1$ and $P2$ with that of the zero point passages of the curve $D3$, derivative of the second derivative $D2$, in the fields where the value of the second derivative $D2$ is higher than one of the experimentally defined thresholds $S2$, as shown in figure 6.

Interpolation procedures which allow to increase the resolution, initially quantified by the length of the scan BI of the camera 2, can be applied.

Another localization criterion of the faces 9 by means of the integral curve I, recorded after each scan BI of the camera 2, consists in searching for the locations corresponding with the maximums of the correlation functions of the second derivative D2 of the integral curve I with a filter C empirically defined and covering the distortions due to the focussing defects.

The filter is empirically calculated by recording a great number of integral curves I for the items 1 of different nature ; by calculating the second derivative D2 of the curves thus obtained way and by extracting a mean curve which is representative of the second derivative D2 ; by sampling this second derivative curve D2 at a rate corresponding with the translation speeds obtained in practice and by optimizing the filter C thus constitutes in order to reinforce its effect in the neighbourhood of the positive maximums.

The shape of the filter (C) thus constituted varies according to the kind of flank in the integral curve. In order to avoid the parallel calculation of two correlation functions, each corresponding with a kind of flank characteristic of the integral curve I, the used method consists in automatically adapting the filter C used with the type of flank searched for in the calculation field of the correlation function.

This is obtained by the local definition of the sign of the first derivative D1 of the integral signal I and to carry out the convolution products required for the calculation of the correlation function while considering the corresponding filter C.

The criterion described above is shown in figure 7, in which C1 and C2 are filters for the rising flank, respectively the descending flank.

The integration of the video signal V at each scan BI may be achieved over the entire scanning BI, or over one or several parts of the scanning BI and can be obtained by means of the known techniques, either on the analog video signal, or after digitization of the signal.

The integration of the video signal V after digitization is especially interesting in the case of a camera 2 with a photosensitive screen plate. Each pixel or element of an image is digitized at the clock rate of the screen plate 4 and the integral I is reduced to the adding of the numeric values of the successive pixels. The partial integration, over a field Z of the video signal, as shown in figure 8 for a particular measurement problem, is in this case particularly simple, as the counting of the clock strokes which command the scanning of the screen plate 4 allows to initiate the addition at a pixel in a defined position and to stop it after the desired number of pixels.

In the case of a matrix screen plate, the integration is performed over the whole or a part of the produced signal during the scanning of each successive line of the screen plate 4.

In the case of a linear screen plate, used in combination with a translation device which moves the item to be measured 1 in front of the sensor, the value of the integral obtained at each scan of the photosensitive line is associated with the reading of the corresponding position of the item in order to obtain the integral curve on which one of the aforementioned criteria is applied to, in order to localize the faces of the object.

It is obvious that many changes can be applied to the example described above, without however leaving the scope of the invention.



Claims.

1.- Method to measure the length of an object (1), method according to which the object (1) is lit in order to form the image (8) of the shadow of said object (1) on a detector (2) with photosensitive screen plate (4), said image of the shadow (8) is scanned in order to obtain video signals (V) for one scanning line (BI) and said signals (V) are processed in order to localize the edges of said image (8) and to deduce thereof the distance between said edges, characterized in that the image (8) is scanned according to several scanning lines (BI), at least in the neighbourhood of the edges, the video signals (V) being integrated on the whole or a part of each of those scanning lines (BI), the evolution of the value of the integral being followed over several successive scanning lines (BI) in the neighbourhood of the edges (9) to be localized, and points are defined in the curve (I) representing this evolution of the integral corresponding with the edges in the image (8) of the shadow.

2.- Method according to claim 1, characterized in that the video signal (V) of each of the scanning lines (BI) is integrated with the analog video signal.

3.- Method according to claim 1, characterized in that the video signal (V) of each of the scanning lines (BI) is integrated after digitization of the video signal (V).

4.- Method according to claim 3, characterized in that the integration is reduced to the addition of the numeric values of the pixels or of the successive image elements.

5.- Method according to one or any of the claims 1 through 4, characterized in that the position of the edges



in the image (8) of the shadow of the object (1) is localized by defining the inflection point of the curve of the integral (I) constituted by the succession of values of the integral (I) obtained after each scan (BI).

6.- Method according to one or any of the claims 1 through 4, characterized in that the position of the edges in the image (8) of the shadow of the object (1) is localized by detecting the point (F) where the curve of the integral (I) constituted by the succession of values of the integral (I) obtained after each scan (BI) reaches a fixed percentage (P) of its total variation (A).

7.- Method according to claim 6, characterized in that said percentage (P) is defined experimentally during the calibration of the instrument.

8.- Method according to one or any of the claims 1 through 4, characterized in that the position of the edges in the image (8) of the shadow of the object (1) is localized by differentiating twice the curve of the integral (I) and by localizing the locations corresponding with the maximums of the second derivative (D2) in the fields where the absolute value of the first derivative (D1) is higher than a threshold (S1) which has been experimentally defined.

9.- Method according to one or any of the claims 1 through 4, characterized in that the position of the edges in the image (8) of the shadow of the object (1) is localized by the localization of the locations corresponding with the maximums of the correlation function of the second derivative (D2) of the curve of the integral (I) by means of a filter (C) empirically defined and covering the distortions caused by to the defects in focussing.

10.- Method according to claim 9, characterized in that a filter (C) is used which is defined empirically by the

analysis of several typical curves of integrals (I) taking the influence of the lack of definition into account.

11.- Method according to claim 9 or 10, characterized in that a filter (C) is used which is optimized in order to amplify the sensitivity of the correlation test in the neighbourhood of the maximums of the second derivative (D2).

12.- Method according to one or any of the claims 9 through 11, characterized in that a filter is used which automatically adapts itself to the kind of flank found in the curve of the integral (I).

13.- Method according to one or any of the claims 1 through 12, characterized in that in the event the analyzed image (8) is reproduced on a matrix screen plate (4), the integration is performed on the whole or a part of the given signal during the scanning of each successive line of the screen plate.

14.- Method according to one or any of the claims 1 through 12, characterized in that, in the event the analyzed image (8) is reproduced on a linear screen plate (4) used in connection with a translation device moving the object to be measured (1) in front of the detector (2), the value of the integral (I) obtained after each scan (BI) of the photosensitive line is associated with the reading of the corresponding position of the object in order to obtain the curve (I).

